A dendrochronological assessment of fire history in a ponderosa pine forest of the eastern Cascades

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INTRODUCTION

Frequency and intensity of fire plays an important ecological role in many plant communities in the Intermountain West. The relationship of fire to climate, pest epidemics and land use has shaped the structure and composition of many ponderosa pine (*Pinus ponderosa*) forest types. Reconstructions of historical fire regimes can reveal important interactions between ecological processes that influence present-day stand dynamics.

This study is part of an effort to quantify the frequency, intensity and seasonality of wildfire in a ponderosa pine community on the eastern slope of the Cascade Mountain Range. The work involves the collection, enumeration and cross-dating of fire events recorded by tree rings in living and dead trees at two locations separated by several kilometers. Associated studies examine the effects of Pandora moth populations (Speer et al. 1997), climate variance (Grissino-Mayer et al. 1997), and tree regeneration (Kennedy Sutherland et al. 1997.) on forest dynamics. The temporal sequences of these effects, revealed by cross-dating the entire set of tree ring chronologies, suggests important ecological interactions, detailed in research reports generated during the 1997 North American Dendroecological Field Week.

METHODS

Study Area

The study area is located in the Deschutes National Forest in Section 11, T12S, R10E, eight km east of the Metolius Research Natural Area (Figure 1). The study area consists of two sites, the Prairie Farm Fire (PFF) site and the Bathroom Fire (BRF) site, at an elevation of approximately 1030 meters. The vegetation community varies from open forests to woodland. This site is classified as "yellow pine forest zone" by Franklin and Dyrness (1988), and is dominated by ponderosa pine. Subdominants include incense cedar (*Calocedrus decurrens*) and western larch *(Larix occidentalis)*. White fir (*Abies concolor*) and Douglas fir (*Pseudotsuga menziesii*) are more common at adjacent higher elevations. Western juniper (*Juniperus occidentalis*) occurs at adjacent lower elevations. The understory consists primarily of bitterbrush (*Purshia tridentata*), squaw carpet (*Ceanothus prostratus*) and green-leaf manzanita (*Arctostaphylos patula*). This plant association is Ponderosa pine-Douglas-fir/Manzanita/Fescue community.

The climate of the region is cool and dry. Records from the Sisters weather station, located 20 km southeast of the study documents that precipitation occurs mainly in the winter and spring months. Summer weather is dominated by high pressure

conditions with orographic precipitation confined primarily to late afternoons. The interannual variability in summer soil moisture is considerable and varies greatly with the presence or absence of El Niño or La Niña conditions, the former promoting reduced moisture, and the latter, increasing moisture compared to normal conditions.

Geology of the area is dominated by acid volcanic rocks, especially tuffs and rhyolites. The resulting soils are relatively thin, fine-grained clays overlying impervious bedrock with high water-holding capacity. These soils reach wilting point while considerable moisture remains, enhancing effects of summer drought on tree growth.

Logging and grazing during the past century has dominated land use in this region. Frequent lightning from convective cells during the dry summer months provide sources of ignition that that maintained frequent fires. Pre-settlement, people also intentionally set wildfires to enhance production of fruits and berries, and to promote open hunting areas (Agee 1993).

METHODS

Field Methods

The study site is selected after initial reconnaisance of the area. Standing live, standing dead, and fallen tree boles are examined for multiple fire scars. Trees with multiple scars are selected and sampled to ensure documentation of the most complete fire record. Few living fire-scarred trees are observed. Scarred trees are sampled to obtain representative sequences of fire events (Arno and Sneck 1973). Flat wedges of wood that included fire scars and intact pith, if present, are extracted with chainsaws. Wedges are removed where scarring and scar condition was optimal. Samples are labeled in the order of removal, and wrapped to prevent damage during transport. Environmental variables including slope, aspect and location are recorded for each tree sampled.

Sample Preparation

The PFF Site yielded 14 sample wedges and three additional stumps were sampled at the BRF Site. Sample wedges are planed and sanded with increasingly fine grit sandpaper (#150, 220, 320). This treatment helped reveal the annual growth rings and fire scar positions. Wedges lacking structural integrity are first glued together with carpenter's glue and surfaced after glue solidified.

Laboratory Methods

Skeleton plots are developed for each sample wedge. Constructing skeleton plots is a method for standardizing tree ring sequences for comparison (Stokes and Smiley 1968). These plots record the sequence of wide and narrow rings, with greater focus on the narrowest rings. Individual skeleton plots are combined to generate a master plot, and crossdated to provide absolute dates for all fire years. The crossdating is aided by comparison to a known master chronology developed for Horse Ridge, 80 km away (Holmes, Adams and Fritts 1986). Seasonality of fire events is estimated by position of cell damage within the corresponding annual ring.

The chronological distribution of fires at the sites is described with the Fire History Program (FHX2.0) (Grissino-Mayer, 1995). The relationship of climate to fire years is analyzed using the EPOCH Program (Grissino-Mayer, 1995). Tree ring indices from the Horse Ridge chronology (Holmes, Adams and Fritts 1986) and the Palmer Drought Severity Index Data retrieved from the International Tree Ring Data Bank (World Data Center, Boulder CO) are used as climate indicators in this analysis. Additional climate-fire frequency analyses are conducted with the DIFMAP Program (Fritts, 1993). DIFMAP utilizes reconstructed precipitation and temperature data since 1602 to examine climatic conditions suitable for fire.

RESULTS and DISCUSSION

Fire Chronology

The period of analysis (1600-1997) is derived from the age-distribution of the scars sampled (Table 1). Seventy-seven fire scars from 11 samples collected from the Prairie Farm Fire site are dated . Twenty-two fire scars are identified from 3 samples taken from the BR Fire site (Figure 1). Sampling from the BR Fire site is not complete and a comparative chronology could not be compared with the Prairie Farm Fire chronology. However, these data can indicate broader-scale fire events. Eight of nine major fires occurred in the same year at both sites.

Descriptive statistics are only performed on data from the Prairie Farm Fire. At this site, 94% of the fires occurred within the 270 year period between 1600 and 1870, during which 19 fire years are recorded. The mean fire interval is 13 years, with fire intervals ranging from 3 to 32 years (Table 1). The Weibull Mean Probability Interval shifted the mean fire interval from 13 to 12.4 years, which indicates a normal distribution. Other studies in dry ponderosa pine forests in central-east Oregon show mean fire intervals ranging from 4-42 years (Weaver 1959, McNeil and Zobel 1980, Bork 1984).

The seasonality of fire events is determined for 74% of the fire scars, 90% of these scars occurred during the late-season. This seasonality in fire events reflects the climatic patterns in the Pacific Northwest of cool, wet winters and springs with dry, warm summer and fall seasons. No other dendrochonology studies attribute seasonality to fire events in this region.

Three distinct patterns of fire frequency occurred between 1600 and present. Fire events through the 1700s appear more heterogeneous than the pattern during the 1800s. This trend can be attributed to higher frequency fire occurrence (Baissan and Swetnam, 1997). The more uniform pattern of fire occurrence in the 1800's may reflect a decline in fire frequency from the pre-settlement period. In the last period, the introduction of livestock in the 1860's and a significant increase in grazing during the 1870's dramatically decrease fine fuel production, an important component of the frequent, low-intensity fire regime characteristic of these forest types. An abrupt disruption of fire occurrence in the fire record suggests change in land-use coupled with fire suppression activities in the early 1900's altered historical fire regimes.

Relationships to Climate

Superposed epoch analysis

A superposed epoch analysis (SEA) (Swetnam 1993) relates fire occurrence to estimates of climate, based on tree ring indices from *Juniperus occidentalis* from Horse Ridge (50 mi. east of our study area), and Palmer Drought Severity Index (PDSI). There is a stronger relationship using tree ring indices from Horse Ridge than coarser-scale PDSI data from the broader eastern Oregon region. A significant relationship in tree ring width and year after fire is apparent. Tree ring width is decreased in the fire year, and is significantly decreased in the post-fire year, indicating drought conditions. This analysis also reveals a pattern of several wet years preceding fire events (Figure 3). The accumulation of fine fuels during wet years followed by dry climatic conditions create a high potential for fire occurrence. This trend has also been shown in southwestern U.S. (Baissan and Swetnam 1990; 1997).

DIFMAP

The results of the DIFMAP analyses are inconclusive. At no point in the analyses did precipitation vary more than 10% from the mean during the 249 year period between 1602-1850. Temperature also remained relatively close to the mean, with no departure from the mean of more than 0.3 of a degree C for any season. Annual readings were within 0.1 of a degree. For fire years and the year immediately preceding and following fire events, no significant conclusions or correlation between climate and fire could be made.

Relationship of fire to Pandora moth outbreaks

Two cycles of Pandora moth infestations were found during the years of the analysis. Pandora moth is a defoliator that feeds on old needles, ignoring new growth. The outbreaks generally span 4 to 18 years, averaging 10 years (Speer 1997). Outbreak cycles can be recorded in tree rings as a succession of narrow rings. The two cycles noted on the study site were from 1843-1850 and 1889-1893. The first outbreak coincides with periods that lack dated fire years. Fires may have been less frequent during this time due to less available fine fuel needles (Speer 1997), or fires were not intense enough to scar the trees sampled. The data set is incomplete during the second cycle of 1889-1893, therefore the lack of fire years dated cannot be attributed to the Pandora moth .

Relationship of fire to stand dynamics

Regeneration studies conducted at this study site indicate that regeneration of present ponderosa pine trees peaked between 1850 and 1900, during a period of moderate fire frequency. Douglas-fir regeneration, however, peaked around the 1920's coinciding with a decrease in fire frequency. Frequent low-intensity fires promote the regeneration of ponderosa pines, a shade-intolerant species able to resist low-intensity fire due to its thick

bark, and requires bare mineral soil for successful regeneration. Douglas-fir, a faster-growing, more shade-tolerant species more susceptible to fire, often outcompeting ponderosa pine seedlings in the absence of fire. Older live trees were less common due to logging activities throughout the late 1800's and early 1900's.

CONCLUSIONS

Several patterns were evident from the fire chronology. Pre-settlement patterns reveal frequent, low-intensity fires while post-settlement patterns document fire suppression. Integration of related results provide clearer understanding of ecosystem interactions; Pandora moth outbreaks may occur during periods of low fire frequency and tree initiation pulses apparently respond to different fire frequencies

Analysis of climatic relationships to fire frequencies reveal increased drought during and proceeding fire, and more favorable climatic conditions prior to fire. These results suggest climate (inferred from tree width ring indices near the study area) provides resources needed for increased fuel load prior to fire and directly increases the risk of a fire event in a given drought year.

Variability in ring-width within years, tree ring complacency (low sensitivity to changes in climate), and a small sample size contributed to uncertainty in our fire dates. Small sample size for living trees (>1900 establishment) also limited our interpretation of the post-1900 fire chronology. Increasing sample size of living trees and trees overlapping with pre-1850 chronologies with post 1850s would permit a more reliable account of the fire history for the area.

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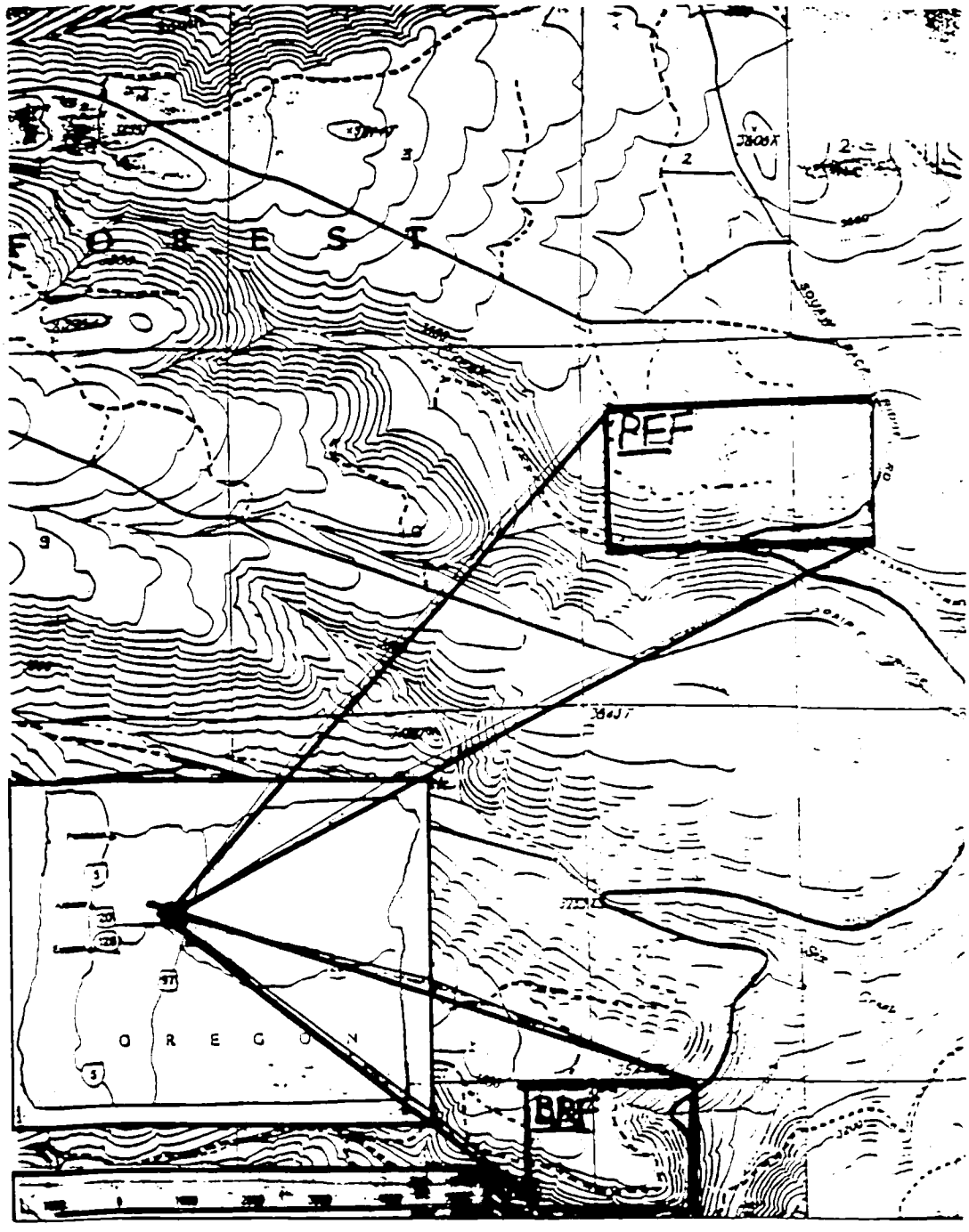
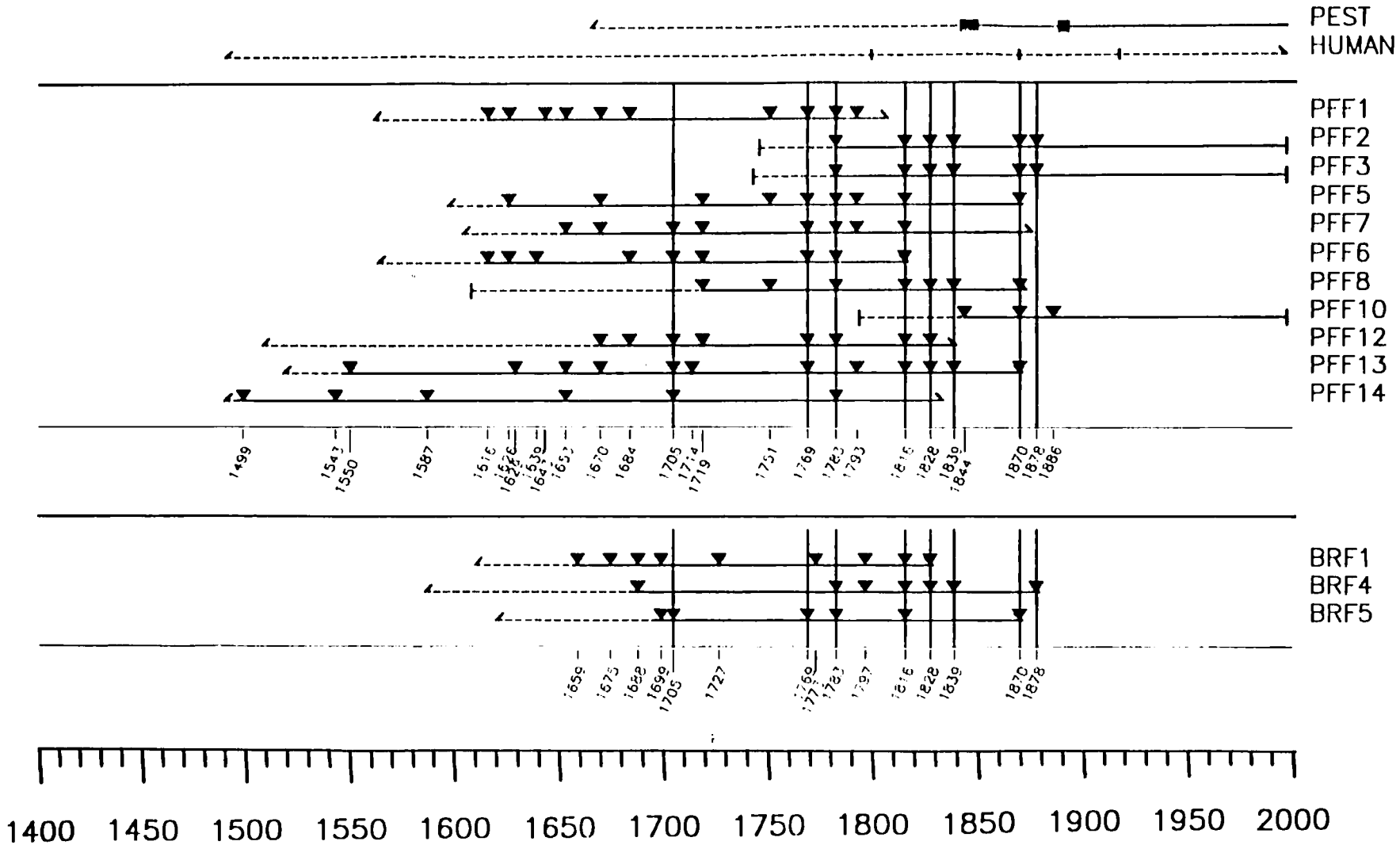


Figure 1: Prairie Farm Fire (PFF) and Bathroom Fire (BRF) sites, Deschutes National Forest, Oregon.


PEST
HUMAN
PFF1
PFF2
PFF3
PFF5
PFF7
PFF6
PFF8
PFF10
PFF12
PFF13
PFF14
BRF1
BRF4
BRF5
1400
1450
1500
1550
1600
1650
1700
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1800
1850
1900
1950
2000

Superposed Epoch Analysis

Prairie Farm Fire